Sorensen
POWER SUPPLIES

instruction manual for

QSA SERIES

HIGH POWER LOW VOLTAGE NARROW RANGE

SORENSEN COMPANY

A UNIT OF RAYTHEON COMPANY

676 ISLAND POND ROAD MANCHESTER, NEW HAMPSHIRE 03103

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SECTION I

INTRODUCTION AND DESCRIPTION

1.1 INTRODUCTION:

1.2 This manual contains instructions for the operation and maintenance of the QSA Series modular, high-power, narrow range dc power supplies manufactured by Sorensen Company, Manchester, N.H. The purpose of the manual is to familiarize the user with the functioning of the units, the various applications for which they may be adapted, and sufficient maintenance data to assure long trouble-free life. The models covered in this book include the 12-9.3, 12-13, 18-6.8, 18-10.1, 28-6.0 and 28-8.8.

1.3 Six major subdivisions of the manual furnish essential information about the units. Section I provides a general description and complete technical specifications and performance curves. Other sections contain operating procedures and instructions for modifying the units to meet different applications, principles of operation, troubleshooting, calibration and performance testing routines and general maintenance. The last section provides a complete parts list giving component descriptions and manufacturer part numbers.

1.4 DESCRIPTION:

1.5 Designed to operate on any one of three single-phase inputs, the units provide highly regulated dc output, each in one of two ranges. Refer to Table 1-1 for operating specifications. A feature of the power supplies is extremely fast recovery time and characteristically low-output impedance.

1.6 REMOTE CONTROL: Adjustment of the output voltage of the supplies is local, i.e., accomplished by a control located on each supply. Voltage regulation is also local; the voltage-regulator circuits hold the power-supply terminal voltage constant (within the specified tolerance). Relatively long leads between power supply and load may allow the load-terminal voltage to fluctuate more than desired. Simple wiring changes and additions will permit the voltage output to be controlled (programmed) at a remote point by either resistance control or signal-voltage control. Equally simple changes may be made to regulate the voltage actually applied to the load, rather than that across the supply terminals.

1.7 DUAL-VOLTAGE RANGES: All supplies have high and low output-voltage ranges. They are normally wired at the factory for high-range output. They may be readily converted to low-range output by minor wiring changes.

1.8 SERIES OPERATION: Two QSA models may be series connected to provide a system output voltage greater than either of the units, connected singly, can supply.

1.9 PARALLEL OPERATION: For applications requiring current higher than the one unit can provide, QSA units may be connected in parallel. For a discussion on the number of units which may be operated in parallel, refer to paragraph 3.24.

1.10 OVERLOAD PROTECTION: All power supplies include overload protection circuits. If the load tends to draw more than a predetermined maximum current, the output voltage and current are both reduced by a current foldback circuit (Figure 1-1).

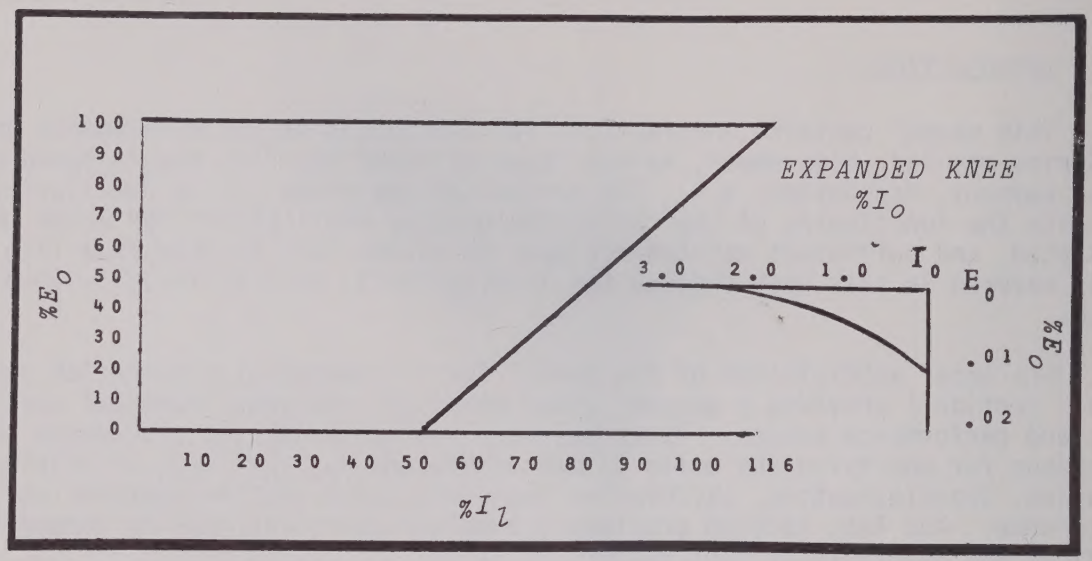

Figure 1-1 Current Foldback Characteristics (typical)

1.11 MOUNTING: The power supplies may be mounted on end, bottom or side, using tapped holes in their enclosures. The enclosures not only provide protection for the circuitry inside but also serve as heatsinks, eliminating the need for external heat-sinking. Note (Figure 1-2) that maximum current depends on the mounting position in some cases.

1.12 OPTIONAL ACCESSORIES:

1.13 Rack adapters (See Figure 1-3, -4, -5) are offered as optional accessories to the power supplies, all designed for standard 19-inch racks. There are six basic rack assemblies to mount various combinations of different power supplies. The rack assemblies include provisions for slide rails and offer added versatility in that units may be mounted both at the front and rear of the adapter. Racks are supplied in 3-1/2 and 5-1/4 inch heights and three depths: 3.62 inches, 18 inches and 20 inches.

There are four filler panels available:

Metered	Unmetered
PM300 3-1/2" height	PF300 3-1/2" height
PM500 5-1/4" height	PF500 5-1/4" height

The metered panels (which can accomodate five meters), include a voltmeter, voltage selection knob, three meter lenses and three meter filler blocks. Consult your factory representative for complete system design.

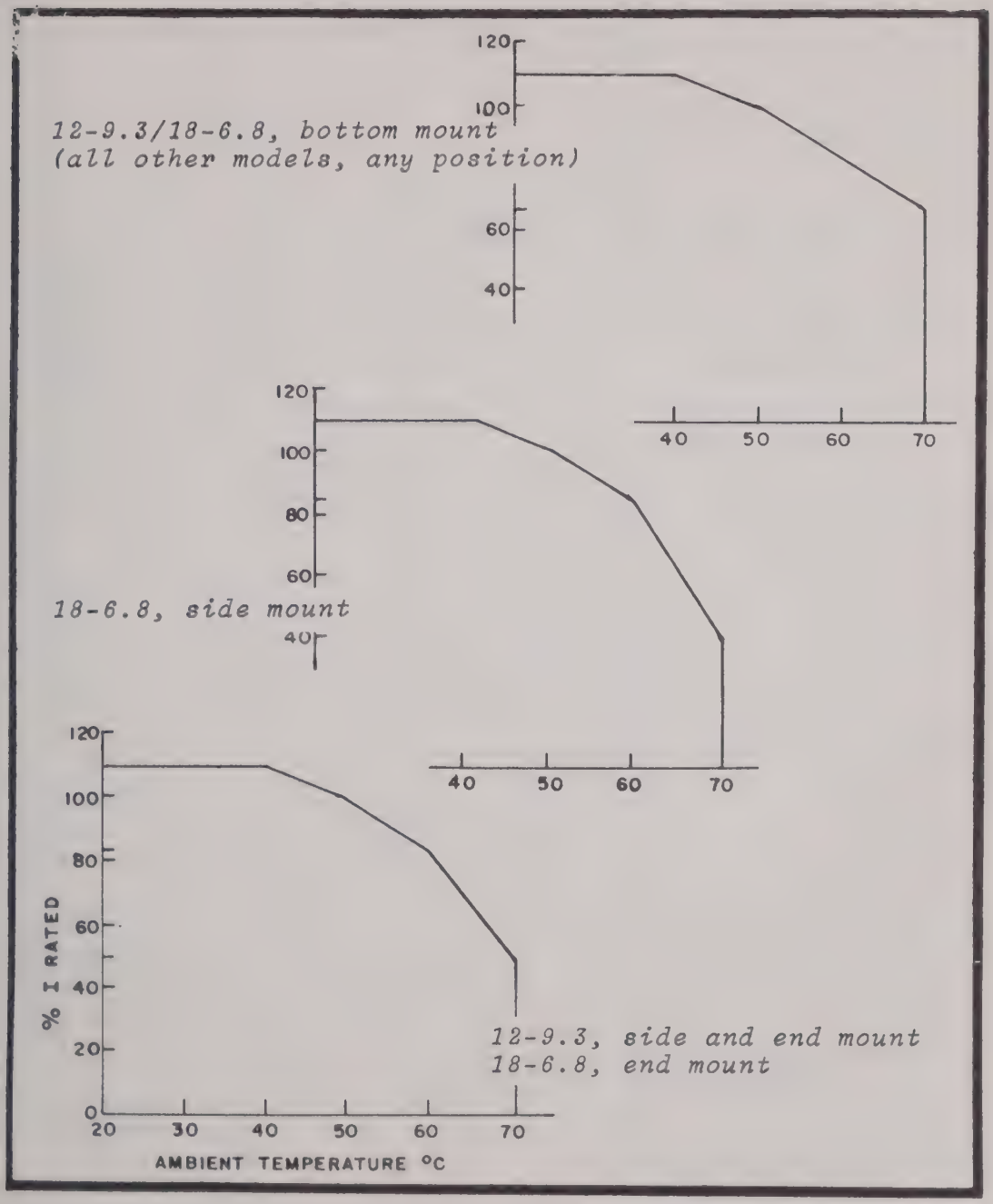

Figure 1-2 Current Derating

Table 1-1 UNIT SPECIFICATIONS

CHARACTERISTIC	MODEL					
	12-9.3	12-13	18-6.8	18-10.1	28-6.0	28-8.8
Input Ratings						
Voltage (Vac) Frequency (Hz)[1] Phase	105-125/200-240/210-250 48-480 1					
Maximum Current (Aac)						
115 Vac input	3.8	5.2	4.0	5.6	4.4	6.0
230 Vac input	1.9	2.6	2.0	2.8	2.2	3.0
Power factor (typical)[2]	0.79	0.8	0.77	0.8	0.78	0.8
Efficiency (%-typical)[2]	43	49	40	46	54	55
Output Ratings						
Voltage (Vdc)						
High range	11-14	11-14	18-22	18-22	26-30	26-30
Low range	8-11	8-11	14-18	14-18	22-26	22-26
Resolution (mV-typical)	35	35	45	45	70	70
Current at 50°C (A)[3]						
High range	0-9.3	0-13	0-6.8	0-10.1	0-6.0	0-8.8
Low range	0-10	0-14	0-7.2	0-11	0-6.2	0-9.3
Current Foldback	Figure 1-1					
Regulation (%)[4]	±0.005					
PARD (ripple)						
RMS 10 Hz-7 MHz bandwidth						
50-60Hz input (uV)	300					
400 Hz input (uV) typical	500					
Peak-to-Peak 3 Hz-25 MHz bandwidth						
50-60 Hz input (mV)	3					
400 Hz input (mV)	10	15	5	10	5	10

[1]Primary wiring change required for all but Model 12-13 when using 400 Hz input.
[2]At nominal input and full-rated output.
[3]See Figure 1-2 for current derating characteristic.
[4]For combined line and load.

Table 1-1 UNIT SPECIFICATIONS (cont'd)

CHARACTERISTIC	MODEL					
	12-9.3	12-13	18-6.8	18-10.1	28-6.0	28-8.8
Transient Response (us) typical[5]	35					
Temperature Coefficient (%/°C)	0.015					
Output Voltage Turn-on and Turn-off Overshoots	None					
Ambient Temperature (°C)	-20 to +71					
Remote Programming						
Resistance	40 ±8 ohms/volt					
Voltage Signal	1 volt/volt					
Output Impedance (R +JwL)						
R (u ohms)	60	50	130	90	225	160
L (uH)				0.2		
Stability[6]	0.025%/8 hours					
Maximum Number of Units						
Series	2					
Parallel	See "Parallel Operation" in Section III					
Remote Sensing Compensation	1.5 volts/load lead (max)					
Cooling	Convection					
RFI (typical)	Meets MIL-I-6181/MIL-I-16910					
Envelope Dimensions (inches)						
Width	7-1/2					
Height	4-15/16					
Depth	9-3/8	11-7/8	9-3/8	11-7/8	9-3/8	11-7/8
Weight (lbs)	22	29	22	29	22	29

[5]For a step-load change, no load to full load, or full load to no load, and recovery to within a ±10 mV band.
[6]Eight hours after warm-up and with constant load, line and ambient termperature.

If the units are to be rack mounted in the AC300 and AC500 optional adapters (Figures 1-3 and 1-4), remove the adapter face plate, position the unit behind the adapter and then secure with hardware enclosed in the bag tied to the adapter handle. Fit the adapter to the rack and attach. Make the necessary input connections (paragraph 2.3), check electrically per paragraph 2-7, and adapt the unit to the desired application (section 3) before installing the face panel. If optional AC318, AC320, AC518 or AC520 rack adapters are to be used, (see Figure 1-5), your factory representative should be consulted.

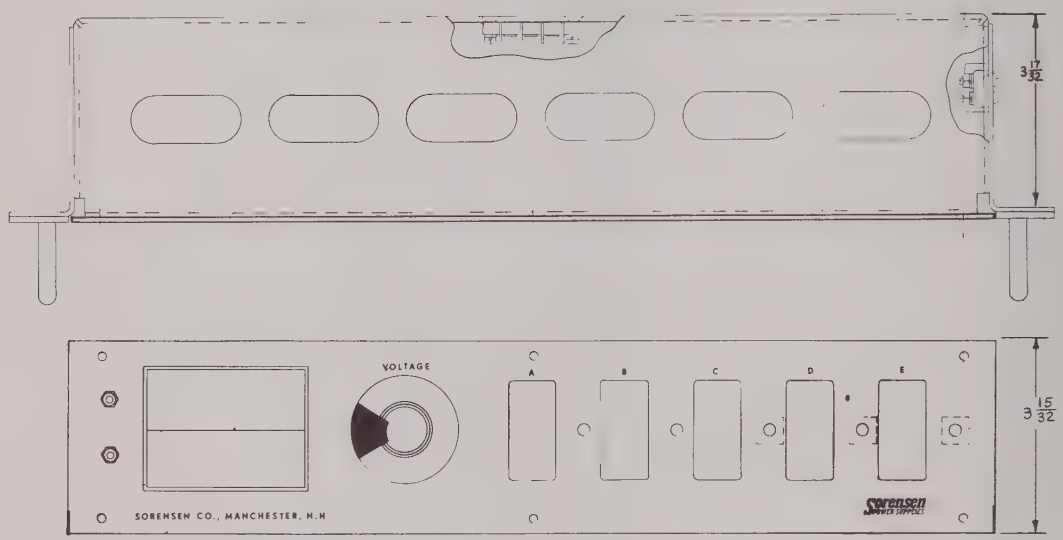

Figure 1-3 AC300 Rack Adapter (shown with metered panel)

NOTE

AC300 can accommodate three Module II or Module III units, or four Module I units.

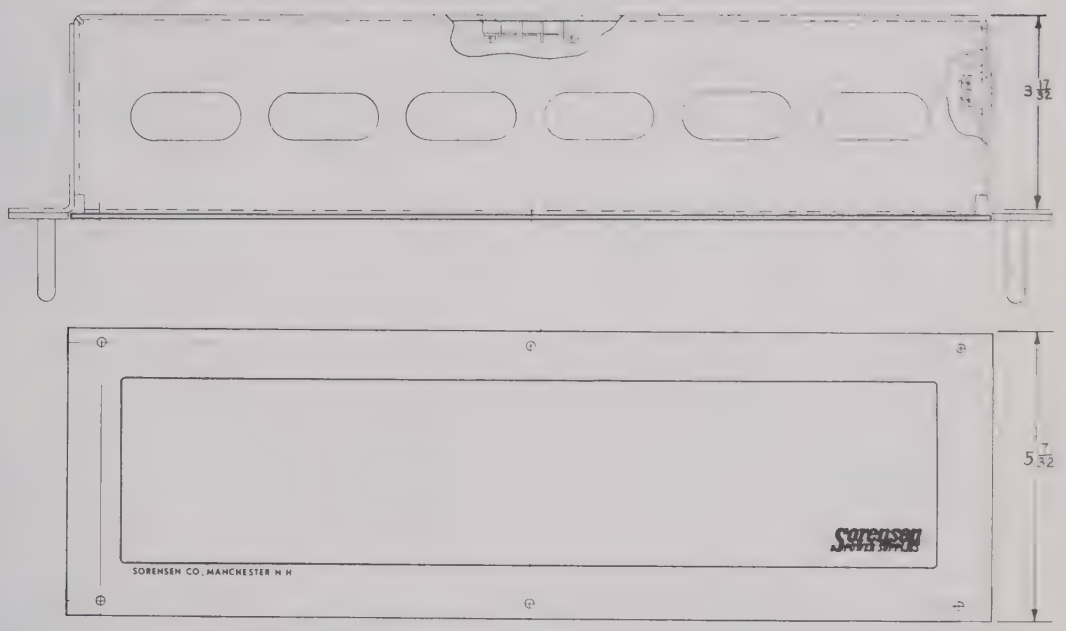

Figure 1-4 AC500 Rack Adapter (shown with unmetered panel)

NOTE

AC500 can accommodate four PTM-DUAL Modules.

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SECTION II

PREPARATION FOR USE

2.1 GENERAL:

2.2 After unpacking, an initial inspection and a preliminary checkout should be performed to assure that unit is in good working order. Basically, these consist of visually checking for damaged parts and components, and of making an electrical check. If it is determined that the unit is damaged, notify the carrier immediately. The carrier's claim agent will then prepare a report of damage. The user is required to send this report to the Service Department, Sorensen Company, Manchester, N.H. Sorensen will advise the user as to what action is required to repair or replace the supply.

2.3 INSPECTION:

2.4 Check for damage incurred during shipment as follows:

a. Inspect enclosure for dents, chips, etc.

b. Check condition of external terminal board. Make certain that all screws are in place and that links are fitted over the barrier strips between the positive OUT terminal (1) and its adjacent SENSE terminal (2) and across the negative OUT terminal (4) and its adjacent SENSE terminal (3).

c. Using a slotted-drive screwdriver, rotate Output Adjust (adjust-access aperture located in nameplate) from stop-to-stop, and turn fully counterclockwise. Rotation should be smooth through a 300-degree angle.

d. Remove screws retaining front header plate, and inspect component board.

e. Remainder of enclosure may be removed by removing mounting screws and hex-head screws at nameplate end. Inspect transformer, capacitors and passing-stage transistors.

2.5 INPUT AND VOLTAGE RANGE CONNECTIONS:

2.6 All models of power supply are normally shipped from the factory wired for 115-volt ac primary input and for output on the high-voltage range. The units may be readily altered for either 220-volt or 230-volt primary input and for low-voltage output by changing taps on the power transformer. Figure 2-1 and schematic diagrams, Figure 5-3A/B contain full instructions for making these alterations. Reassemble the unit following these changes.

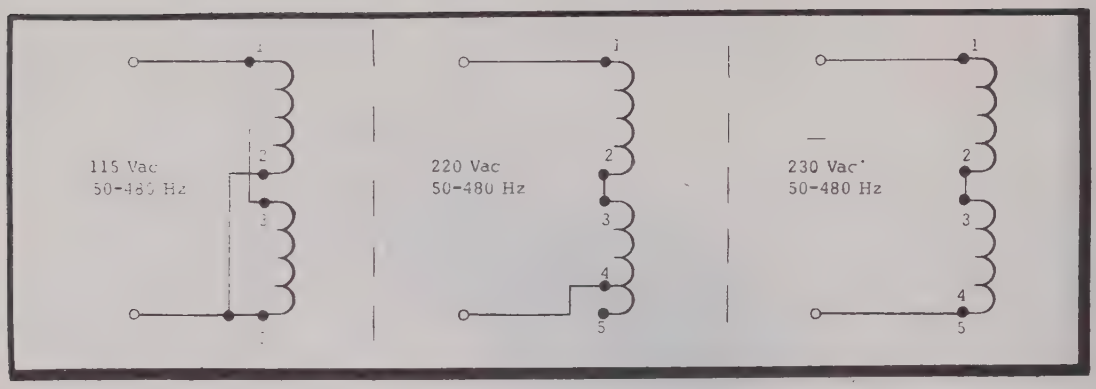


Figure 2-1 Input Connections

NOTE

When changing the primary connections for 220-V input, capacitor C4 remains connected between terminals #1 and #5. When the secondary is rewired for Low Output Range, capacitors C1 and C2 remain connected between terminals #16 and #18, and #16 and #14 respectively.

2.7 ELECTRICAL CHECK:

2.8 The initial electrical check is performed as follows:

a. Make sure that the unit is positioned so that a free flow of air is available.

b. Connect the primary input leads to terminals TB1-10/TB1-11 of the unit terminal board. Terminal TB1-9 may be used for an input system ground.

c. Connect a dc voltmeter across terminals TB1-6 (+) and TB1-7.

d. Apply primary input power.

e. Rotate the Output Adjust control through its entire range. The voltmeter should vary over the range specified in Table 1-1.

f. Remove input power.

2.9 MOUNTING:

2.10 These power supplies may be mounted on a chassis, panel, cabinet, etc., in any of three different ways. Tapped mounting holes are provided on the terminal panel end, the left side (viewed from the terminal panel end), and the bottom, of the enclo-

sures. In all cases, a cutout must be made in the exterior mounting surface to provide a free flow of air to that side of the supply. Figure 2-2 shows the mounting-hole and minimum cut-out dimensions for all three methods. Use 10-32 mounting screws, removing existing screws from the mounting holes as necessary. In determining the length of the mounting screws, allow for washers and mounting surface thickness, and add 3/8 inch for maximum thread engagement in the mounting holes. Derate the maximum current as shown in Figure 1-2 as necessary.

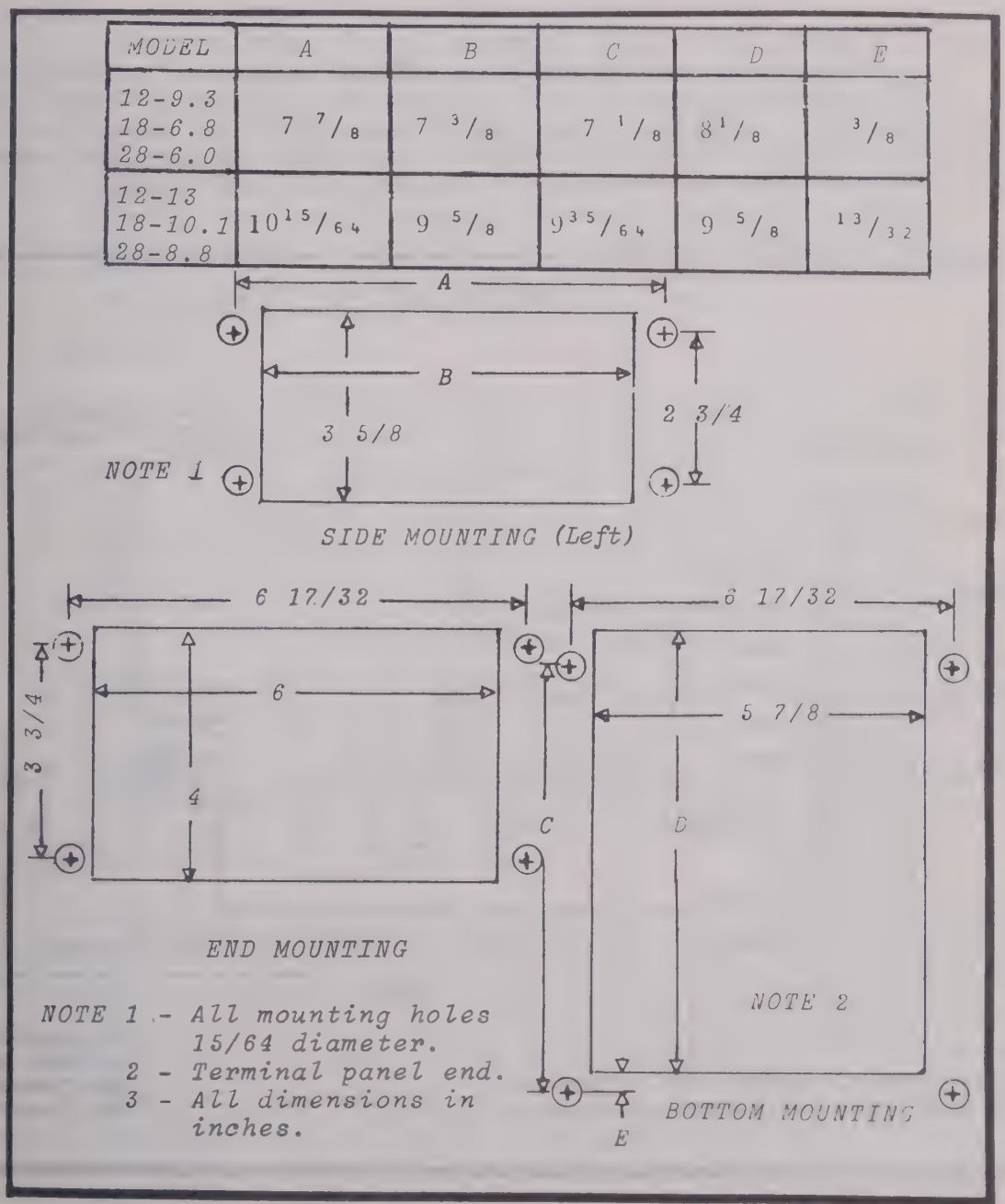


Figure 2-2 Mounting Hole and Cutout Dimensions

CAUTION

The cutouts are required for dissipation of the heat generated by the supplies. Do not reduce their dimensions, nor otherwise impede the natural flow of air around the supplies.

2.11 If units are to be rack-mounted in an optional adapter (Figure 2-3), remove the face plate (for front mounting only). Attach the units to the front or rear adapter, as desired, using the hardware in the bag tied to the adapter handle. Before replacing the face plate or otherwise making the assembly inaccessible, check Section III and make any adjustments required for the particular application.

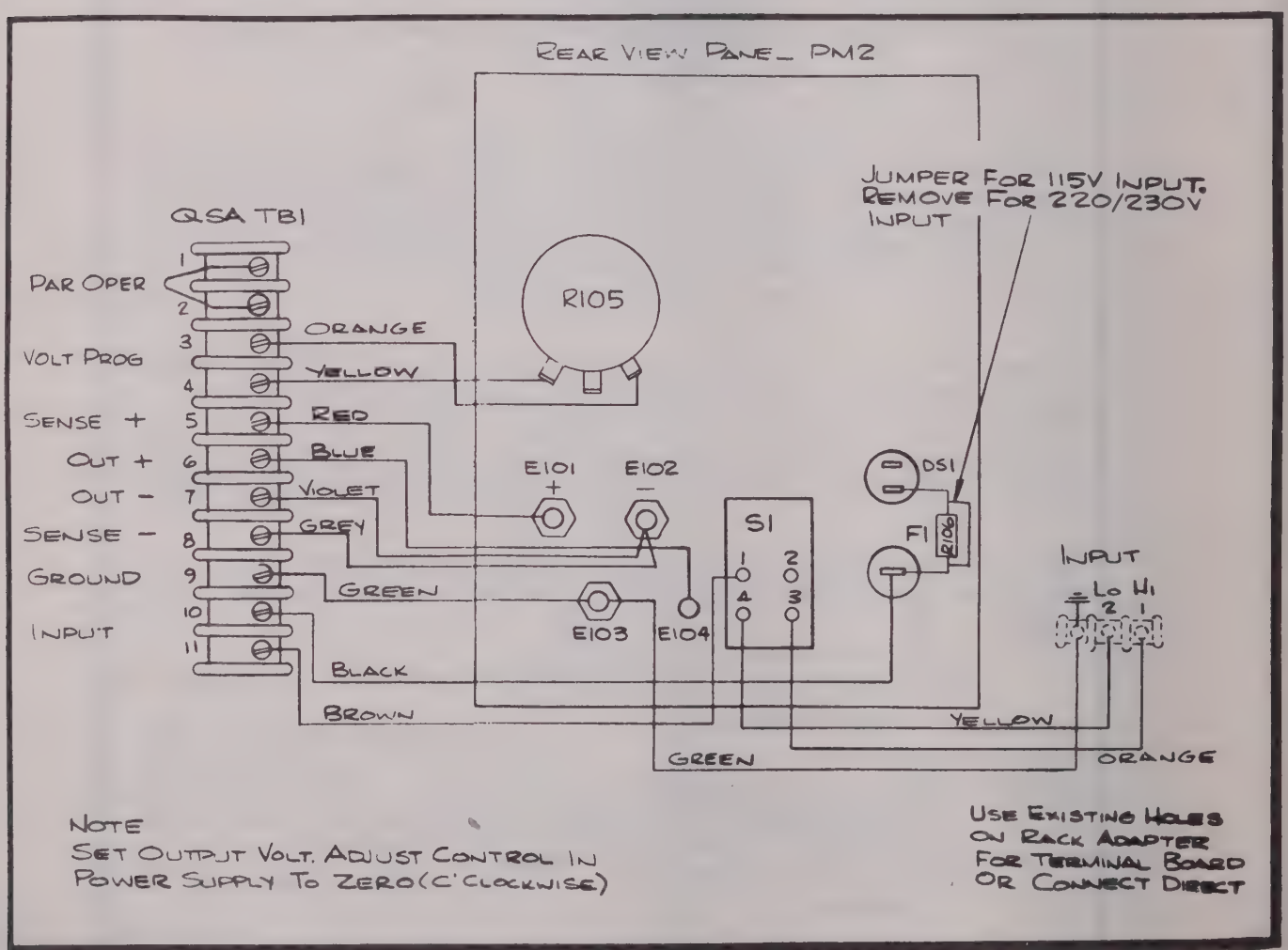


Figure 2-3 Rack Adapter Panels, Meter Wiring

SECTION III

OPERATING INSTRUCTIONS

3.1 GENERAL:

3.2 This Section contains instructions for adapting these power supplies to, and operating them in, a number of applications. These include remote sensing, remote programming, and series and parallel operation.

CAUTION

The sensing and power circuits in these supplies form a closed loop. Opening this loop by removing a terminal-board link or disconnecting a sensing or programming lead will result in high unit output and may damage the supply or the load.

3.3 CONTROLS:

3.4 The power supplies each have four screwdriver-adjustable controls, accessible through holes in the terminal-panel end of the power-supply enclosures. The names, functions, and access-hole location of these controls are:

a. OUTPUT ADJUST CONTROL (R18)-sets output voltage at any point within range and resolution of supply-top center of panel.

b. SHORT CIRCUIT ADJUST CONTROL (R26)-sets output current flow with short-circuit across output terminals - above and to left of fuse post.

c. FOLDBACK ADJUST CONTROL (R5)-sets value at which output current begins to decrease with increasing load - directly below R26 access hole.

d. COMPARISON BRIDGE ADJUSTMENT CONTROL (R15)-used to adjust the output voltage range of the unit - top left of the panel.

3.5 ROUTINE OPERATION:

3.6 The power supplies are ready to operate as they are shipped from the factory, and are normally connected and adjusted for local sensing, local control of voltage, and operation on the high-voltage range. All that need be done is to make the input and output connections and adjust the output voltage to the desired value. However, a number of modifications of the factory connections and adjustments are possible. Two of these, altering the input connections to correspond to the primary voltage available, and changing the output voltage range, have already been discussed in Section II and must be made, if needed, before applying primary power. In addition, a number of modifications of adjustment and connection are discussed in the following paragraphs of this Section III. Some of these are optional, some are mandatory, as - for example - the derating and readjustment of the supplies for operation in

temperatures above 50°C. The user should consider all these modifications and determine if any are necessary or applicable to his circumstances. Having done so, the supply may be connected and placed in operation.

a. Connect the primary input wires to terminals TB1-10/TB1-11 on the unit terminal panel.

b. If a primary system ground is desired, connect this to terminal TB1-9.

c. Connect a voltmeter across terminals TB1-6 and TB1-7. Apply primary power and adjust the output voltage to the value wanted with the OUTPUT ADJUST CONTROL. The output voltage should not exceed that shown in Table 1-1.

CAUTION

If the supply has been modified for remote sensing (discussed later), make sure that terminal TB1-5 is connected through the load and sensing leads to terminals TB1-6 and TB1-7 is similarly connected to TB1-8. If not, an excessive and uncontrollable output voltage will result.

d. Remove the primary power and connect the load across terminals TB1-6 (+) and TB1-7. The supply is now ready for operation.

3.7 CURRENT/TEMPERATURE COMPENSATION:

3.8 All models of power supply are protected from overload - including complete short-circuit - by internal circuitry which functions automatically. When the load tends to draw more than a safe amount of current, the output voltage and current decrease with the amount of overload (current foldback). At short-circuit, the output voltage drops to zero and the current assumes a minimum safe value. The point at which the current begins to decrease with increasing load, and the current value at short-circuit, are both adjustable. At the factory, the start of current foldback is set at 107% of the normal maximum operating current at 50°C: the short-circuit current is set at 52%. With these adjustments, the supplies may be operated at any ambient temperature between 0°C and 50°C. If a supply is to operate in an ambient temperature higher than 50°C, the foldback and short-circuit currents must be reset for proper protection. The new currents are first calculated, then the controls are adjusted to correspond.

3.9 Compensation Calculation: To calculate the foldback and short-circuit currents:

a. Measure the temperature of the environment in which the unit will operate. Find this temperature along the horizontal axis of the appropriate sheet of Figure 1-2.

b. Extend a vertical line upward until it intersects the curve. Extend a horizontal line from the intersection to the left until it meets the vertical axis. The intersection here is the percentage of derating.

c. Multiply this percentage (expressed as a decimal) by the output current at 50°C (Table 1-1). The figure obtained is the new, maximum operating current at the higher ambient temperature.

d. The current foldback point is taken as a percentage of the derated maximum operating current. An arbitrarily safe percentage figure may be used, or a percentage may be used which takes into account the temperature sensitivity of the current-foldback circuit. Both methods are described in the following subparagraphs.

(1) Multiply the new operating current maximum by 1.1. The result is the new foldback current value, without regard to the temperature characteristics of the foldback circuit.

(2) Alternatively, multiply the new operating current maximum by X% (expressed as a decimal), where

$$X = 107 + \Delta T\ (0.06),$$

ΔT being defined as

$$\Delta T = 40 - (\text{actual ambient in } ^{\circ}C).$$

The result is the new foldback current value, with the foldback circuit temperature characteristics taken into account.

e. Compute the new short-circuit current value as 52% of the new maximum operating current.

3.10 Sample Calculation: Assume a bottom-mounted Model 12-9.3 is to be operated in an ambient temperature of 62°C on its high-voltage range:

a. Derating percentage = 80% (Figure 1-2).

b. Maximum operating current at 50°C = 9.3A (Table 1-1).

c. 0.80 x 9.3 = 7.44A (maximum operating current at 62°C).

d. 7.44 x 1.1 = 8.18A (new current-foldback setting).

e. 7.44 x 0.52 = 3.87A (new short-circuit current setting).

3.11 FOLDBACK AND SHORT-CIRCUIT ADJUSTMENT:

3.12 To adjust the foldback and short-circuit current controls:

a. Rotate the Foldback Adjust potentiometer R5 fully clockwise and the Short-circuit Adjust potentiometer R26 fully counterclockwise.

b. Connect a voltmeter across the output terminals of the supply. Apply nominal input voltage and adjust the output voltage to the lower limit of the unit's range. Alternatively, if the supply is to be used at a fixed voltage above the lower limit, set the output voltage to the fixed value.

c. Remove the input power and connect an ammeter (±0.5%) and a variable load resistor in series across the output terminals.

d. Reapply the input power and adjust the load until the ammeter reads the calculated value of foldback current.

e. Adjust R5 until the current just begins to drop.

f. Place a jumper across the load resistor. Adjust R26 until the ammeter reads the calculated value of short-circuit current. Remove the jumper.

CAUTION

In adjusting R26, do not allow the short-circuit current to rise more than 10% above the calculated value. A current excessively higher than the calculated value may damage the power supply.

g. Repeat steps d-e-f until the specified currents are obtained with no further adjustment of R5 or R26.

h. Make a final check by increasing the load resistance until the current drops appreciably below the foldback current. Then decrease the load resistance slowly to zero. The current should rise to the foldback value, then drop to the short-circuit value as the load resistance decreases progressively to zero.

3.13 REMOTE SENSING:

3.14 As shipped, these power supplies are connected to sense (regulate) the voltage appearing at their terminal-panel connections. The power supply connections may be rearranged to sense the voltage actually applied across the load. This rearrangement will compensate for up to 1.5 volts drop in each load lead. To use this feature:

a. Remove the links between the terminal pairs TB1-5/TB1-6 and TB1-7/TB1-8.

b. Connect the power supply to the load as shown in Figure 3-1. Use coaxial cable for the sensing leads at TB1-5/TB1-8, connecting the shield of the cable to TB1-8.

c. Place the unit in operation as described in paragraph 3.5.

NOTE

The transient response of the power supply will degenerate slightly when using remote sensing. If this is undesirable, remove the output capacitor C7 (see schematic diagram) and reconnect it directly across the load terminals. An electrically identical capacitor may be used, if desired (see Parts List).

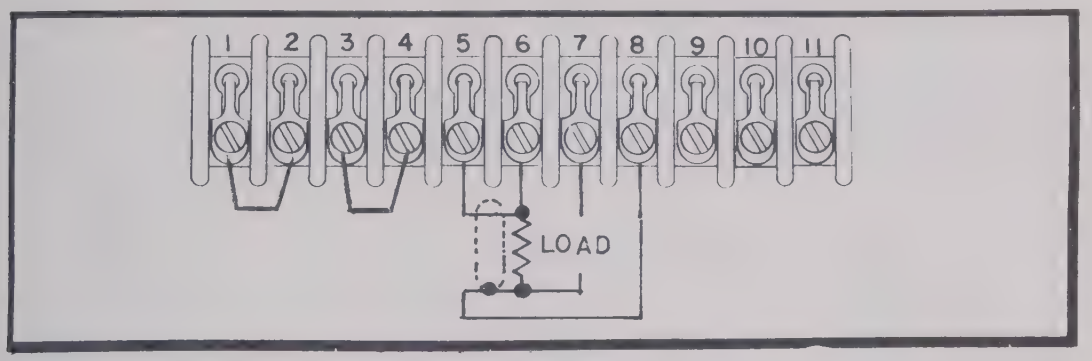


Figure 3-1 Remote Sensing

3.15 REMOTE PROGRAMMING:

3.16 The factory-shipped unit is connected for local control of output voltage by varying the setting of the OUTPUT ADJUST CONTROL. If it is desired to control the output voltage from a remote point, this may be done by either a remote resistance control or by supplying a voltage signal from the remote point. Both methods are described in the following subparagraphs.

3.17 RESISTANCE PROGRAMMING: The value of the programming resistance must be 40 ohms, ±8 ohms, for each volt of output required. Thus, for 12.5 volts output, (12-volt models), a resistance of approximately 180 ohms is needed. The resistor must have a temperature coefficient of not greater than 30 ppm/^{o}C and must carry the programming current of 25 mA. Its wattage rating must be at least 10 times the calculated dissipation. Alter the power-supply connections in the following manner:

CAUTION

The programming resistance value must not be larger, in terms of 40 ohms/volt, than the maximum voltage rating of the supply. A larger resistor will force the supply to operate outside its ratings, with possible damage and loss of regulation.

a. Turn the OUTPUT ADJUST CONTROL fully counterclockwise. This control will not be used in this application.

b. Remove the link between terminal pair TB1-3 and TB1-4 and connect the programming resistor across these terminals. Use twisted-pair or shielded wire between the resistor and the terminal board - if shielded wire is used ground the shield at TB1-9 (see Figure 3-2).

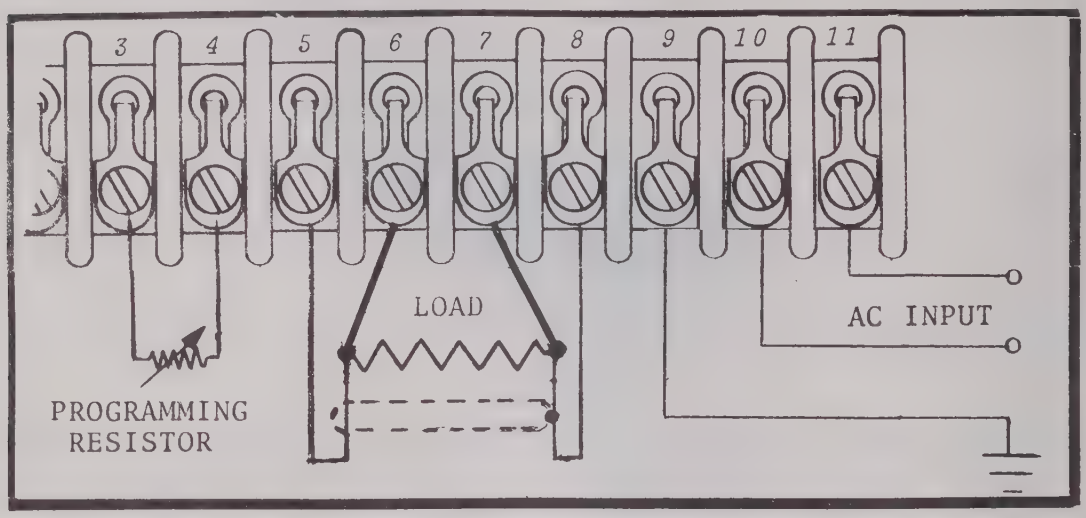


Figure 3-2 Remote Programming

c. With no load, apply primary power and measure the output voltage to verify that it is the desired value.

d. Shut off the primary power and place the unit in operation as described in paragraph 3.5.

3.18 VOLTAGE PROGRAMMING: The value of the voltage-programming signal must be 1 volt for each volt of power-supply output, but never greater than the maximum voltage rating of the supply (see the CAUTION under Resistance Programming, preceding, the sense of which applies here). The signal source must be floating (ungrounded) and capable of absorbing the 25 mA programming current. Noise and ripple on the signal will tend to appear in the power supply output.

3.19 The alteration of the power-supply connections is identical to that for resistance programming, except the signal source is connected across TB1-3/TB1-4 instead of the programming resistor.

3.20 SERIES OPERATION:

3.21 Two units may be connected in series to give up to twice the output voltage of one unit. Maximum current output will be the same as for one unit. Voltage regulation will be the sum of the individual voltage regulations.

3.22 When operating units in series, rectifiers, mounted on heatsinks, must be connected across the individual unit outputs. Table 3-1 lists the recommended rectifiers and heatsinks. It is assumed that one forward and one reverse polarity rectifier will be mounted on each heatsink. If not, a separate heatsink must be used for each rectifier.

3.23 To connect two units in series, see Figure 3-3, and:

a. Remove the link between terminal-pair TB1-7 and TB1-8 on one of the units. For convenience, this will be referred to as Unit 1.

b. Connect a lead from TB1-6 of Unit 1 to the positive side of the load.

c. Connect a lead from TB1-7 of the other unit (Unit 2) to the negative side of the load.

d. Connect TB1-7 of Unit 1 to TB1-6 of Unit 2.

e. Run a sensing lead from TB1-8 of Unit 1 to TB1-6 of Unit 2.

f. If local sensing is to be used, skip this step. For remote sensing, remove the links between terminal pairs TB1-5/TB1-6 of Unit 1 and TB1-7/TB1-8 of Unit 2. Run sensing leads from TB1-5 of Unit 1 and TB1-8 of Unit 2 directly to the load, as shown.

g. Place the units in operation as described in paragraph 3.5.

Table 3-1 Rectifier Recommendations, Series Operation

QSA MODEL	DESCRIPTION	SORENSEN PART NO.
High Power, Narrow Range	DIODE, 1N1200	587393-1

Models	Heatsink Dimensions (1/32" aluminum)
28-6.0	2 1/4" x 2 1/4"*
18-6.8	2 3/4" x 2 3/4"*
28-8.8	2 1/2" x 2 1/2"**
12-9.3	2 1/2" x 2 1/2"**
18-10.1	3" x 3" **
12-13	3 3/4" x 3 3/4"**

*Mica Washer
**No Washer

3.24 PARALLEL OPERATION:

3.25 The number of units which may be paralleled, using the master-slave approach, is dependant on the amount of current available to drive the slave-unit passing stages. This current is a variable from unit to unit and depends on dissimilarities, within accepted tolerances, in component characteristics. The maximum number of

units which may be paralleled is therefore a function of the master or control unit selected. Under the most unfavorable conditions, at least four units may be paralleled. If the tolerances in the master unit accumulate in the favorable direction, it is possible to parallel up to 15 units. Derate each unit to 90% of its maximum operating output current. The total current capability will be the sum of the derated currents.

3.26 The following procedure relates to paralleling two units - it need only be extended to parallel up to the maximum number. The error-control signal from the master is brought out, midway of the error-amplifier chain, and connected to the same point in the slaves. The portion of the error-amplifier chain in the slaves, preceding this point, is disconnected. Control of the output voltage of all units is accomplished at the master, by the master OUTPUT ADJUST potentiometer or the remote programming circuit, if used. To connect two units in parallel:

a. Remove the link between terminals TB1-1/TB1-2 of the slave unit (Figure 3-4).

b. Connect a lead from terminal TB1-1 of the master unit to TB1-1 of the slave unit.

c. Connect leads to the load from terminals TB1-6 and TB1-7 of both units, as shown, observing proper polarity.

d. If local sensing is to be used, skip this step. For remote sensing, remove the links between terminal-pairs TB1-5/TB1-6 and TB1-7/TB1-8 of the master and run sensing leads from TB1-5/TB1-8 of that unit directly to the load, as shown.

e. Place the units in operation as described in paragraph 3.5.

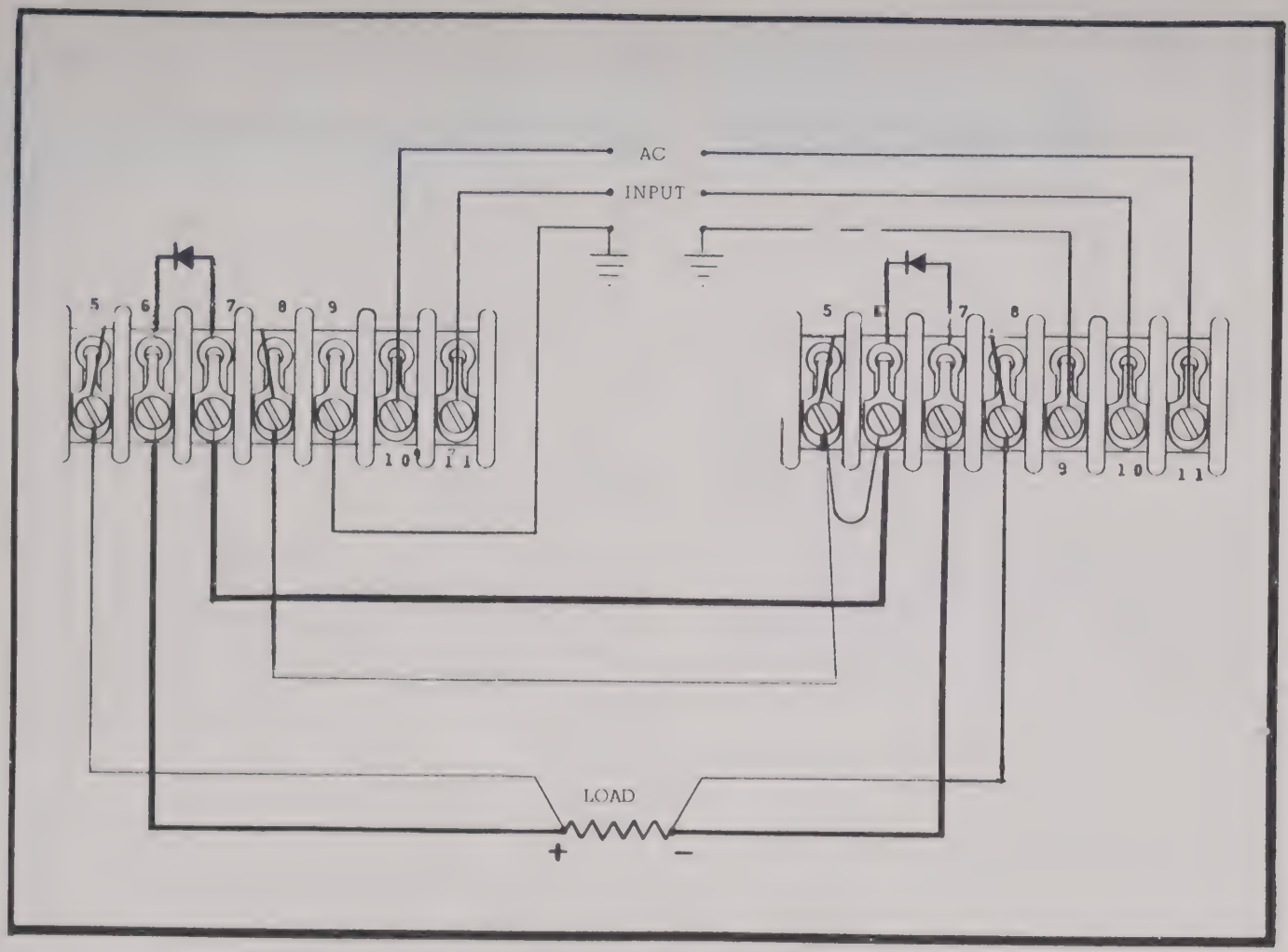


Figure 3-3 Series Operation

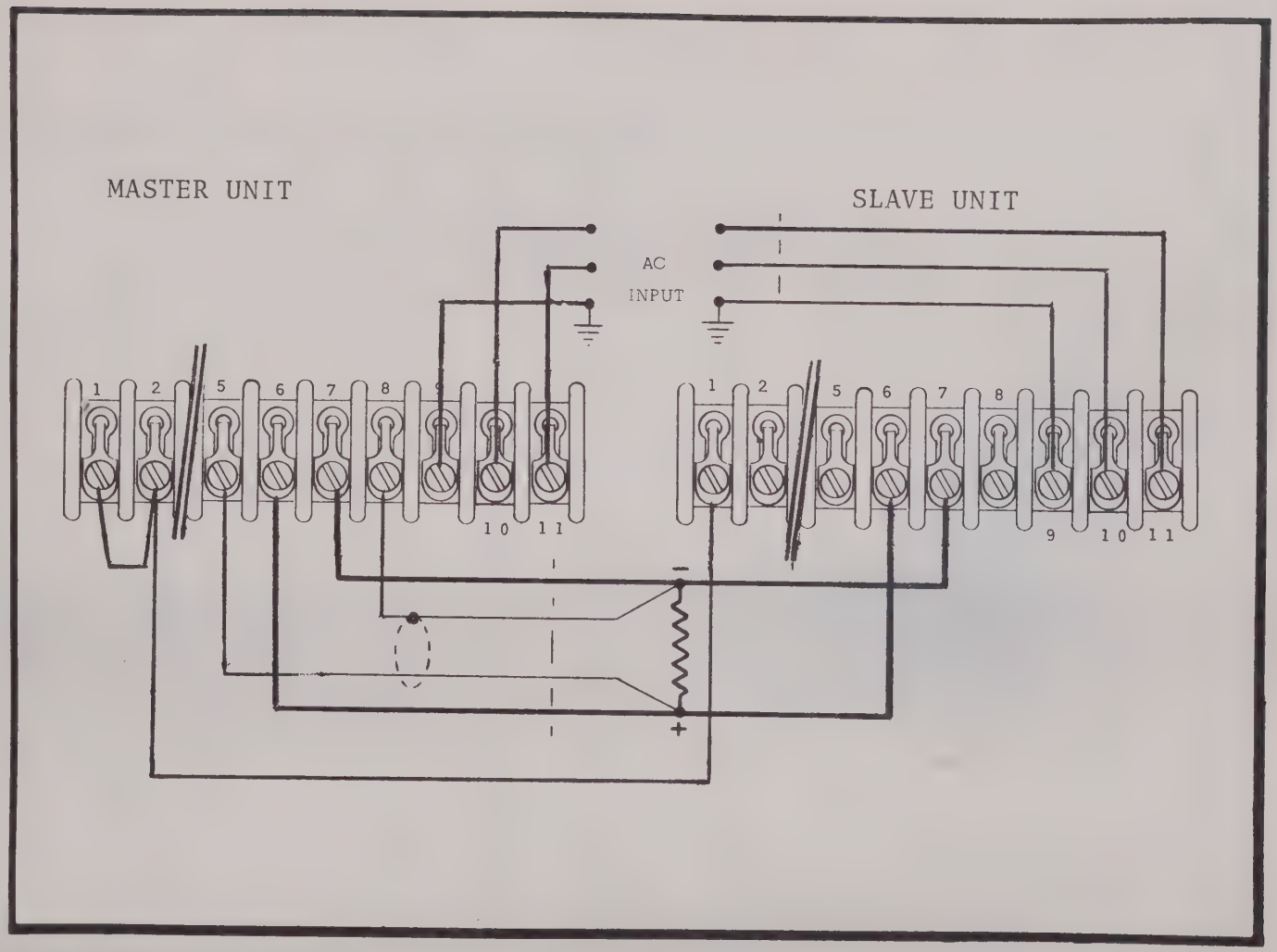


Figure 3-4 Parallel Operation

SECTION IV

PRINCIPLES OF OPERATION

4.1 GENERAL:

4.2 This section discusses unit operating principles. Its function is to impact a sufficient knowledge of the unit circuitry which, when used with the troubleshooting data in Section V, will enable the rapid isolation of unit faults.

4.3 Due to some minor differences between Models within the QSA Series, separate discussions of certain sections are provided. These will be noted as they appear.

4.4 PASSING-STAGE PRINCIPLE:

4.5 The supplies utilize the series-passing-stage principle in regulating unit output. With this approach, a variable impedance absorbs the difference between the desired regulated output and the filtered "brute-force" dc. The variable impedance is provided by a transistor stage which is fed an output-related control signal. Passing operation is idealized in Figure 4-1.

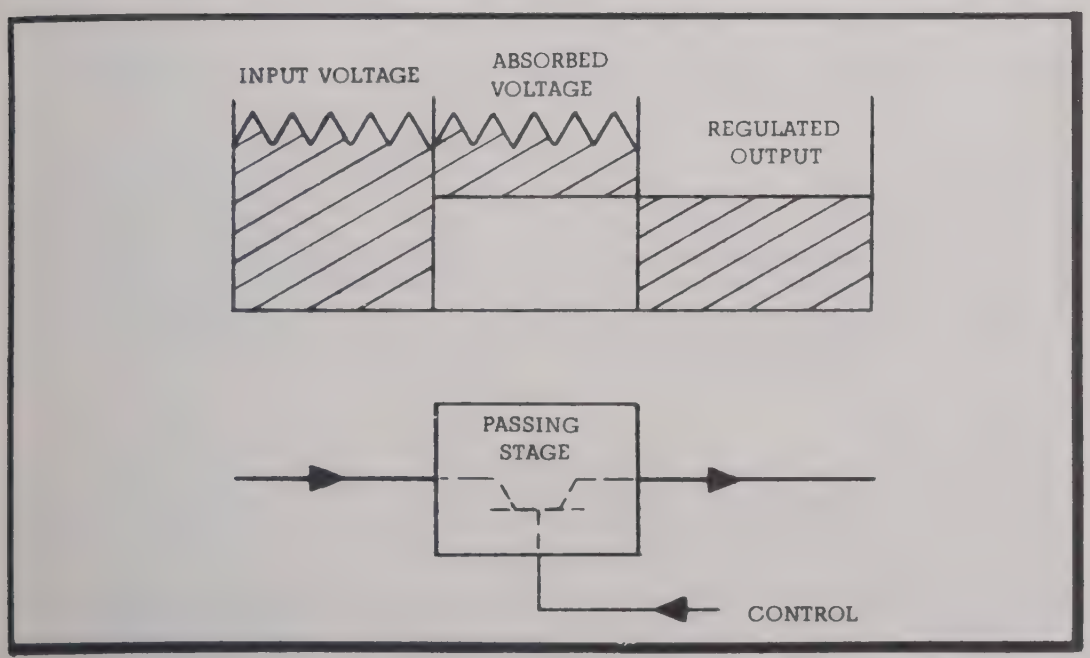


Figure 4-1 Series Passing Stage Principle

4.6 BLOCK-DIAGRAM DISCUSSION:

4.7 Referring to Figure 4-2: The transformer steps down the ac input and applies it to a full-wave bridge rectifier. Output from the rectifier is fed through a passing stage to the load. This passing stage is the regulating device, absorbing the difference between the rectifier and desired output voltages. The feedback loop to the passing stage includes a sensing bridge, which compares a portion of the unit output against a fixed reference. Bridge-derived error signals, differentially amplified, vary the drive current to the passing stage, thereby changing stage impedance (and therefore IR drop) as a function of unit output.

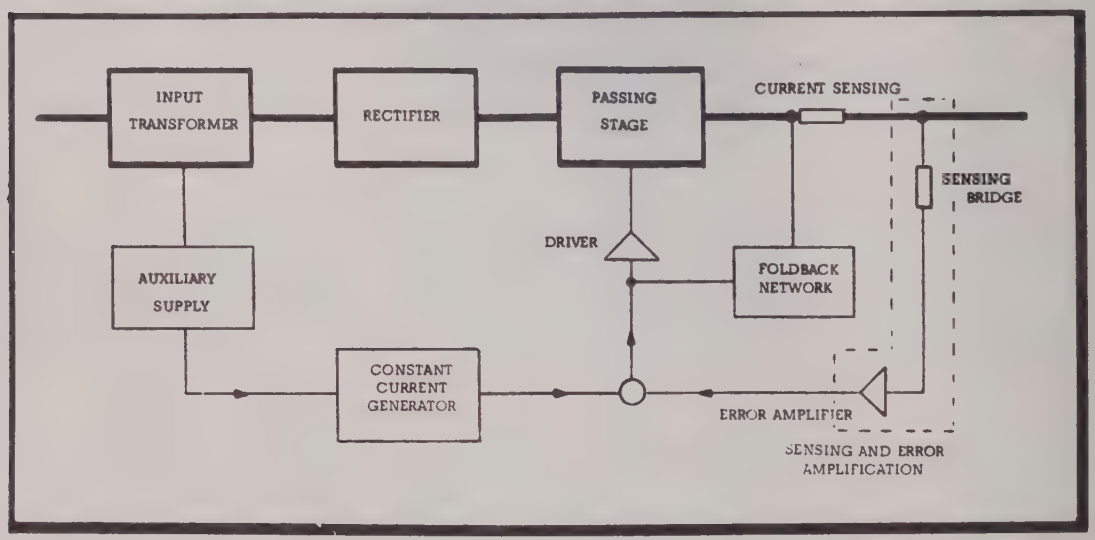


Figure 4-2 Block Diagram

4.8 Overcurrent protection is provided by the foldback section, which, in the event of a short circuit, overload or unit malfunction, reduces the drive on the passing stage by providing an alternate path for the current output of the constant-current generator.

4.9 OUTPUT-POWER SOURCE:

4.10 The source of the output power delivered to terminals TB1-6/TB1-7 is the ac potential developed across power transformer terminals T1-13/T1-15 (or T1-13/T1-14). The ac voltage at these terminals is full-wave rectified by bridge rectifier CR4-CR7 and filtered by capacitor C3. The positive leg of the dc output across C3 is connected to output terminal TB1-6 via the pass transistors Q2-A-B-C, etc., and resistor R7; the negative leg goes directly to TB1-7. The output voltage across TB1-7/TB1-6 is, then, the difference between the dc voltage across C3 and the voltage drop across Q2-R7 (the drop across R7 is negligible).

4.11 ERROR AMPLIFIER:

4.12 The error amplifier consists of the two differential-amplifier stages, Q8/Q9 and Q6/Q7. Input stage Q8/Q9 derives its operating voltages and currents from the output voltage at TB1-6/TB1-7: The collectors via resistors R10/R11, the emitters via R13/R17/R18, the base of Q8 from the essentially constant voltage drop across zener diode CR8, and the base of Q9 from the arm of potentiometer R15. The setting of R15 and the parameters of the Q8/Q9 stage are such that with 7.9 volts drop across R15 the bases of Q8/Q9 are at the same potential and the voltage difference between the collectors of these transistors is also approximately zero. Any tendency of the voltage across R15 to change will alter the balance of Q8/Q9 and cause a voltage difference to develop between the collectors of this stage. This difference is applied as a signal through the following stages of the regulator circuit to change the impedance of the pass transistor Q2, restoring the voltage across R15 to 7.9 V again - or very nearly so.

4.13 Error Signals: i.e. voltage differences, developing between the collectors of Q8-Q9 are applied from base to base of the error-amplifier output stage Q6-Q7. The amplified output signals at the collector of Q6 go to the base of driver stage Q4.

4.14 DRIVERS:

4.15 Cascaded driver stages, emitter-followers Q4/Q3 (and Q5 in some models), act as current amplifiers of the error signals out of the Error Amplifier. Their function is to develop sufficient current to drive the bases of pass transistors Q2, increasing or decreasing the impedance of Q2 as determined by the nature of the error signals.

4.16 PASS TRANSISTORS:

4.17 Pass transistor Q2 (four in some models of these power supplies, five in others) act as an automatically variable impedance in series with the external load applied to terminals TB1-6/TB1-7. As more or less drive current is supplied from Driver stage Q5, in response to error signals from the Error Amplifier, the impedance of Q2 is varied in a direction to hold the voltage drop across R15 constant, and for any setting of OUTPUT ADJUST control R18 and to also hold the voltage between TB1-6/TB1-7 constant. This regulator action occurs with either changes in load-current demand or changes in primary line voltage. The impedance of Q2 also changes automatically to allow intentional variation of the output voltage by adjustment of R18.

4.18 VOLTAGE REGULATOR:

4.19 The Error Amplifier, Driver, and Pass Transistors, constitute the voltage-regulator circuit in the power supplies. Their operation can be seen most easily by example. Note that the Error Amplifier resistor R15 is an element in a series-connected divider including R17 and R18; all three resistors are connected across the output terminals TB1-6/TB1-7. It follows that if the output voltage changes, the drop across R15 will tend to change. Assume that the output voltage tends to drop because of an increase in load current demand or a decrease in primary input voltage. The potential at the base of Q9 will move in the negative (less positive) direction. Immediately, this error signal appears in amplified form as a potential difference between the col-

lector of Q8-Q9, the collector of Q9 moving in the positive direction and the collector of Q8 moving negative.

4.20 The amplified error signal from Q8-Q9 is applied to the bases of Q6-Q7 and appears as a still further amplified output at the collector of Q6, from where it is fed to the base of Driver stage Q4 as a positive-going signal. This causes the emitter current of Q4 to increase, and - in order - the emitter currents of Q3 and Q5. The additional current flowing into the base-emitter junction of Q2 decreases the impedance of these transistors, the voltage drop across Q2 decreases, and the load voltage tends to rise. The rising output voltage increases only as far as the original value, at which time the potential across R15 is restored to 7.9 V (actually, a negligibly small amount less than the original voltage in both cases), and the Error Amplifier is in balance again. Similar reasoning will show that an undesired increase of output voltage will also be held to an inconsequential amount by the Voltage Regulator, except that the signal polarities and current changes will be in opposite direction.

4.21 Adjustment of R18 will allow the output voltage to change in spite of the regular action. Assume that the amount of R18 in the circuit is increased. This causes the voltage drop across R15 to decrease in output voltage and sees this as an apparent decrease in output voltage and responds by decreasing the impedance of pass transistors Q2 until the drop across R15 is again 7.9 V. The output voltage is not higher, because of the change in the ratio of resistors R15/R17/R18.

4.22 CONSTANT-CURRENT GENERATOR:

4.23 Collector current to Q6 and drive current to the base of Q4 are supplied from a constant-current generator consisting of Q1 and associated circuitry. Power for the generator is obtained from transformer winding T1-11/T1-12, rectified and filtered by CR1-C1. A constant-voltage, base-emitter bias source for Q1 is provided by the voltage drop across diodes CR2/CR3. Current output is taken across the collector of Q1 and T1-11. As the collector current of Q6 varies with changing error signals at the base of Q6, any tendency of the total current through Q1 to vary is stopped by a change in emitter bias, i.e. a change in voltage drop across resistor R1. It follows, therefore, that any change in current to Q6 is matched by an equal and opposite change in drive current to the base of Q4, since the total current to Q4-base/Q6-emitter remains constant.

4.24 CURRENT-FOLDBACK SECTION:

4.25 This portion of the power-supply circuitry provides overload and short-circuit protection. When the power supply is overloaded, the circuitry not only prevents the output current from rising beyond a safe maximum, but actually causes the current to decrease (foldback) with increasing load. With a short-circuit load, the current is reduced to a safe minimum (but not zero).

4.26 The current-foldback circuit is composed of transistors Q10-Q12 and related components. Normally, Q10/Q11 are cut off and Q12 is saturated. The biasing conditions which set the operating points of the three transistors are determined by the voltage drop across diode CR13 and the settings of Foldback Adjust potentiometer R5 and Short-circuit Adjust potentiometer R26. Increasing load current through resistor R7A tends to move the base of Q11 in the positive direction with respect to its emit-

ter, via R5, but up to the current foldback point (determined by the setting of R5) Q11 remains cut off and no further action takes place in the foldback circuit. Beyond the foldback point, the increasingly positive base of Q11 causes increasing current flow through that transistor, the emitter coupling between Q11-Q12 results in diminishing current through Q12 (since the sum of the Q11-Q12 currents remains approximately constant), and the voltage drop developing across resistor R28 swings the base of Q10 positive with respect to its emitter. The resultant current flow through Q10, drawn from the Constant-current Generator, reduces the drive current to the base of Q4 and thence via Q3, etc., reduces the drive current to Q2. The increasing impedance of Q2 causes the power supply output voltage and current to drop, the effect increasing as the overload is increased.

4.27 As the overload increases to short-circuit, Q11 saturates at a base voltage determined by the drop across R7 and the setting of Short-circuit Adjust potentiometer R26, holding the short-circuit current to a minimum value.

4.28 SUPPLEMENTARY VOLTAGE SOURCES:

4.29 Supplementary voltage sources provide internal power for various uses. In all models of these power supplies, rectifier-filter CR9/CR10 supplies biasing voltage in the current-foldback circuit. In some models, CR11/CR12 and C15 furnish voltage to the collectors of Driver stages Q3/Q4.

Table 6-1 Replacement Parts List (cont'd)

REF DES	PART NUMBER	DESCRIPTION	U/O CODE
Resistors: (ohm, ½W, ±10% unless noted)			
R1	27-1109	390	1-6
R2	27-156	680	1-6
R3	27-152	2.2k	1
	27-133	10k	2, 4
	27-292	3.3k	3, 5
	27-179	15k	6
R4	27-103	1k	2
	27-295	1.5k, 1	4
	28-705	2.7k, 1	6
R5	29-544	5k, 2, ±20%, Pot	1-6
R6	28-117	27.4k, ±1%	1, 2
	28-1307	56.2k, ±1%	3, 4
	28-1323	82k, ±1%	5, 6
R7	27-496-6	0.39, 5, ±5%	1, 2
	27-496-2	0.67, 5, ±5%	5
	28-544	0.5, 5, ±5%	
R8	27-1110	1.2k	1-6
R9	28-1212	182, ±1%	1-6
R10	27-176	1.8k	1-6
R11	27-176	1.8k	1-6
R12	27-160	68	1-6
R13	27-152	2.2k	1-6
R14	27-174	2.7k	1-6
R15	29-486	2k, 4	1-6
R16	Not Used		
R17	28-1213	182, ±1%	3, 4
	28-1214	422, ±1%	5, 6
R18	29-483	400, 4, Pot	1, 2
	29-484	600, 4, Pot	3, 4
	29-485	1k, 4, Pot	5, 6
R19	Not Used		
R20	Not Used		
R21	27-1156	2.7k, 2	1, 2
	27-499-16	4.7k, 5	3, 4
	27-499-14	6.8k, 5	5, 6
R22	190-3908	0.007	1, 2
	190-3909	0.018	5, 6
R23	28-729	1.8k, 1	1, 2
	27-1183	3.9k, 2	3-6
R24	27-1182	270, 2	1
	27-499-13	200, 5	2
	27-466	450, 5	3, 6
	27-457	300, 5	4
	27-458	600, 5	5
R26	29-544	5k, 2, ±20%, Pot	1-6
R27	27-1109	390	1-6
R28	27-133	10k	1-6
R29	Not Used		
R30	Not Used		
R31	Not Used		
R32	Not Used		
R33	Not Used		
R34	Not Used		
R35	Not Used		
R36	27-599-1	75, 10	1, 4
	27-599-3	50, 10	2, 6
	27-599-14	100, 10	3
	27-599-2	150, 10	5
Transformer:			
T1	126-3049		1
	126-3057		2
	126-3050		3
	126-3058		4
	126-3051		5
	126-3059		6

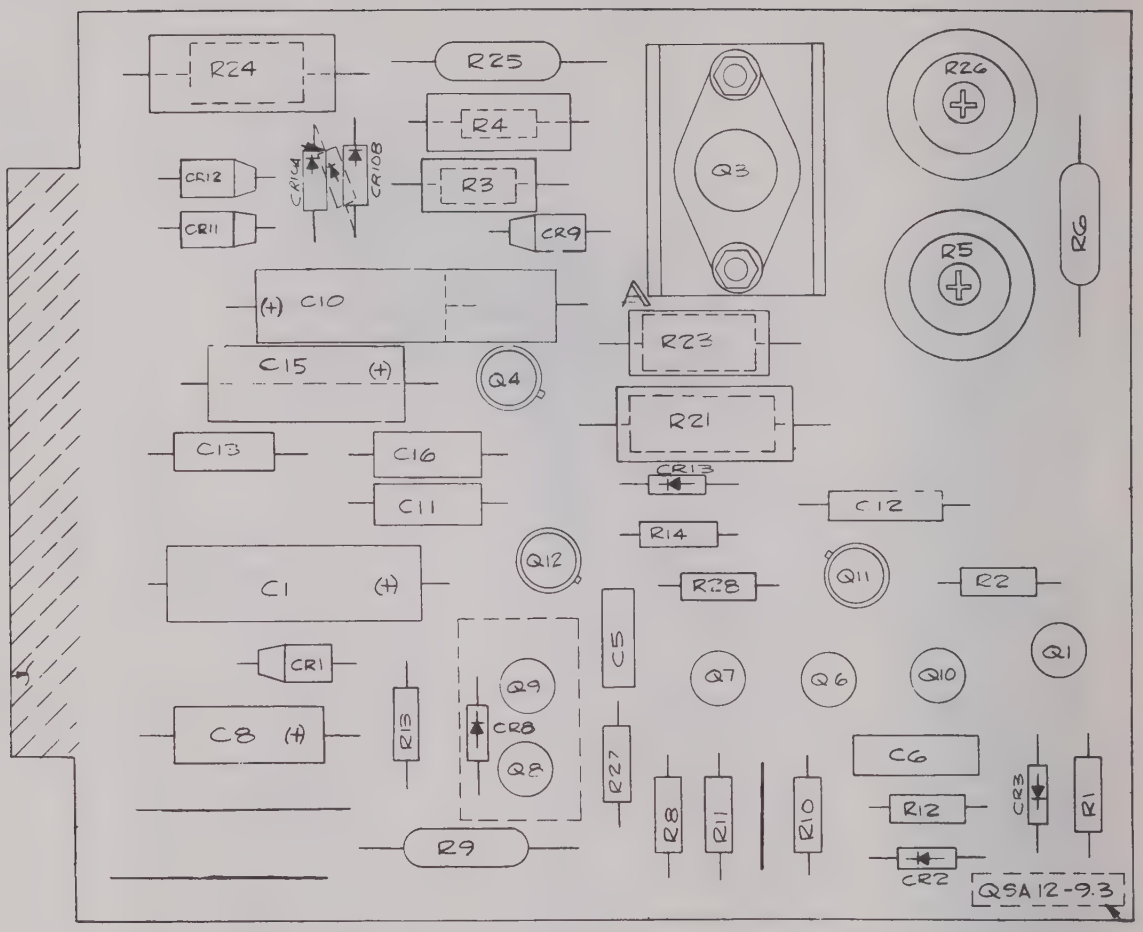


Figure 5-1 Typical Component Board

d. Apply a nominal 115-V input to terminals TB1-10/TB1-11. Voltmeter should indicate between 7.8 and 8 volts. If it does not, use potentiometer R15 to adjust.

e. Remove input power, and reconnect voltmeter across terminals TB1-7/TB1-6. Select a voltmeter range compatible with unit output ratings.

f. Apply nominal input power and rotate Output Adjust from stop-to-stop. At left-hand stop, voltmeter should indicate no more than the minimum value of the unit's specified range, and at right-hand stop, at least the maximum value.

g. Remove input, disconnect voltmeter, and before remounting enclosure, apply locking compound to potentiometer R15.

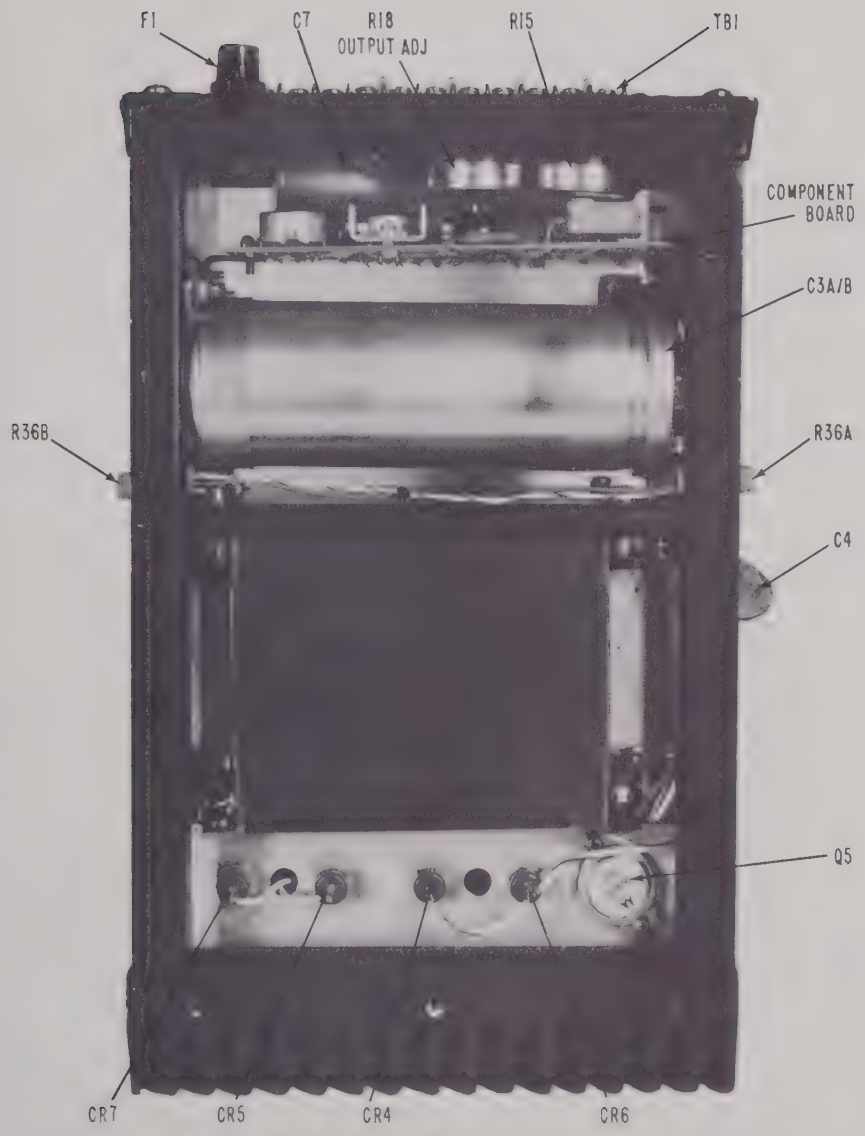
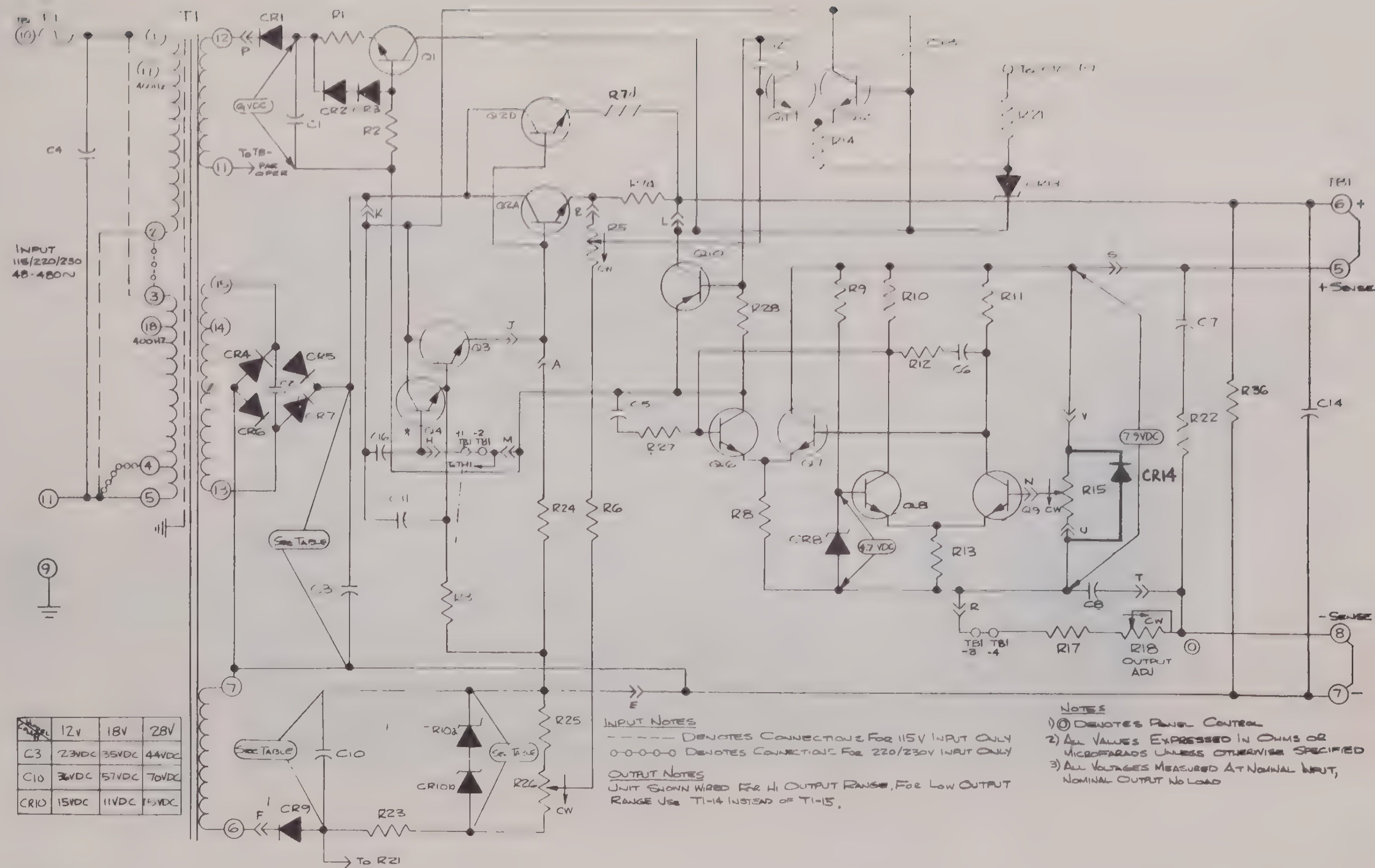
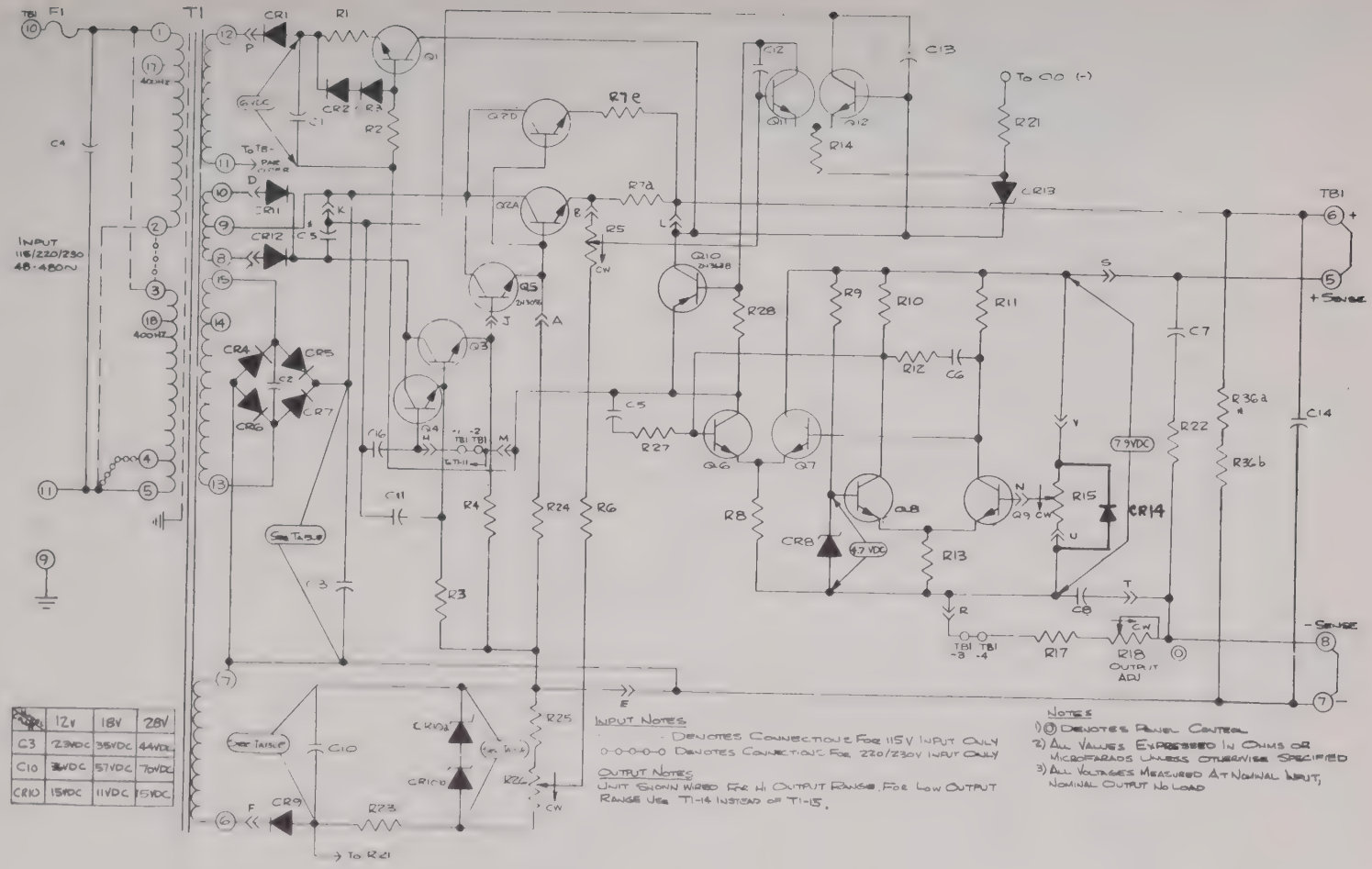


Figure 5-2 Partial Disassembly


T1
CR1
R1
Q1
CR2, R3
C1
R2
C4
INPUT 115/220/230 48-480~
To TB- PAR OPER
Q2D
Q2A
R7
R5
CW
Q10
R28
R9
R10
R11
R12
C6
C5
R27
Q3
Q4
TB1 TB1
R24
R6
R8
CR8
4.7 VDC
Q8
Q9
R13
R15
CR14
7.9VDC
C7
R22
R36
C14
TB1
+ Sense
- Sense
C8
R17
R18
OUTPUT ADJ
TB1 TB1 -3 -4
CR4
CR5
CR6
CR7
See Table
C3
C10
CR9
R23
To R21
CR10
R25
R26
INPUT NOTES
– – – – – DENOTES CONNECTIONS FOR 115V INPUT ONLY
O-O-O-O-O DENOTES CONNECTIONS FOR 220/230V INPUT ONLY
OUTPUT NOTES
UNIT SHOWN WIRED FOR HI OUTPUT RANGE, FOR LOW OUTPUT RANGE USE T1-14 INSTEAD OF T1-15.
NOTES
1) ◎ DENOTES PANEL CONTROL
2) ALL VALUES EXPRESSED IN OHMS OR MICROFARADS UNLESS OTHERWISE SPECIFIED
3) ALL VOLTAGES MEASURED AT NOMINAL INPUT, NOMINAL OUTPUT NO LOAD

	12V	18V	28V
C3	23VDC	35VDC	44VDC
C10	36VDC	57VDC	70VDC
CR10	15VDC	11VDC	14VDC

Figure 5-3A Schematic Diagram, 120W Models



	12V	18V	28V
C3	23VDC	35VDC	44VDC
C10	34VDC	51VDC	70VDC
CR10	15VDC	11VDC	15VDC

Figure 5-3B Schematic Diagram, 180W Models

5.10 CURRENT FOLDBACK: Current-foldback adjustment procedures are covered in paragraphs 3-7 through 3-12, inclusive.

5.11 PERFORMANCE TESTING:

5.12 OUTPUT RIPPLE: To measure output ripple, proceed as follows:

a. Connect a test set-up as shown in Figure 5-4. Set oscilloscope for 1 mV/cm vertical and 10 ms/cm horizontal. (Oscilloscope should have at least a 30 MHz bandwidth.) Select a 150-V range for ac voltmeter. Choose a 1-mV range for RMS meter and a range for the dc ammeter compatible with unit's rated output current. Use a resistive load with a current-drawing capacity greater than unit's rated output. Use the differential voltmeter as a VTVM. Select a range consistent with the rated output of the supply (Table 1-1); either high-voltage or low-voltage output, as desired.

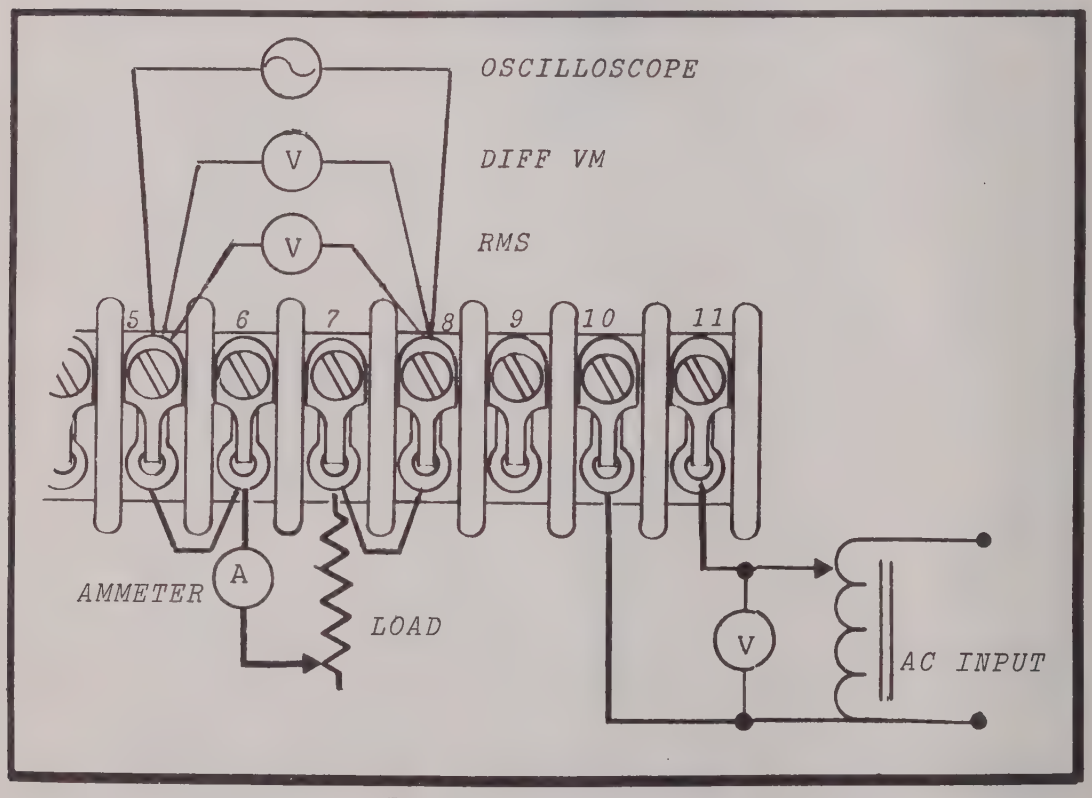


Figure 5-4 Performance Test Setup

b. At no load, apply a 115-Vac, 60-Hz input, and adjust to the output voltage specified in Table 5-2.

c. Apply load and observe oscilloscope and RMS voltmeter. Voltmeter should indicate no more than 0.3 mV; oscilloscope should display a peak-to-peak voltage no greater than 3 mV.

d. If desired, check regulation per paragraph 5.13.

5.13 REGULATION: To measure unit's output regulation, proceed as follows:

a. Connect unit to test set-up shown in Figure 5-4. The oscilloscope and RMS voltmeter are not necessary. Convert the differential voltmeter to the differential mode. Select an internal voltage equal to the value in Table 5-2 (Output Voltage), and set the meter null sensitivity to 10 mV.

b. Apply a 115-Vac, 60-Hz input, and adjust the supply output voltage to obtain a null indication on the voltmeter with no load.

c. With ac voltmeter indicating 115 Vac, increase load on unit until dc ammeter reads the current specified in Table 5-2. Record the deviation from voltmeter null position.

d. Adjust voltmeter internal voltage to regain null position. Then with full load on unit, vary input voltage at 60 Hz from 105 to 125 Vac. Note the deviation.

e. Sum the deviations recorded in steps c and d. The total should not be greater than the regulation specified in Table 5-2.

Table 5-1 Troubleshooting Data

SYMPTOM	PROBABLE CAUSE
No Output	a. Transistor Q1, Q2(1)-(2), Q3, Q4 or Q5 open. b. Diode CR1 open. c. Transistor Q11 shorted.
High Output	a. In constant-current generator, transistor Q1 shorted, or diode CR2 or CR3 open. b. Driver Q3, Q4 or Q5 shorted. c. Passing stage Q2(2) shorted. d. Potentiometer R15 or R18 defective. e. Amplifier transistor Q6 or Q9 open. f. Amplifier transistor Q7 or Q8 shorted. g. Zener reference diode CR8 open.

(1)Parallel passing stage, if any, may be damaged as a result of an open Q2.
(2)When replacing Q2, apply silicon oil to both sides of wafer. Mounting-screw torque is 10 lb-in.

Table 5-1 Troubleshooting Data (cont'd)

SYMPTOM	PROBABLE CAUSE
Low Output	a. In constant current supply, diode CR1 shorted. b. In amplifier, transistor Q6 or Q9, or zener diode CR8 shorted. c. In amplifier, transistor Q7 or Q8 open. d. In foldback circuit, transistor Q11 shorted.
Foldback Circuit Inoperative(3)	Transistors Q10, Q11 open or Q12 shorted.
Ripple Specifications Degenerate	Open CR4, CR5, CR6 or CR7(4)

(3) Without foldback, no protection is provided for the passing stage, bridge rectifiers or input transformer. In any of these components fail, check foldback circuit before returning unit to service.

(4) Complementary rectifier will be overloaded if one of the bridge rectifiers opens. Check before returning unit to service.

Table 5-2 Performance Test Data

MODEL	OUTPUT VOLTAGE (V)		CURRENT (A)		REGULATION (mV)	
	Hi-V	Lo-V	Hi-V	Lo-V	Hi-V	Lo-V
12-9.3	12	8	10.2	11.0	1.2	0.8
12-13			14.3	15.4		
18-6.8	18	14	7.4	7.9	1.8	1.4
18-10.1			11.1	12.1		
28-6.0	28	22	6.6	6.8	2.8	2.2
28-8.8			9.8	10.2		

SECTION VI

REPLACEMENT PARTS LIST

6.1 INTRODUCTION:

6.2 This section provides a coded replacement parts list, keyed to the schematic diagram.

6.3 USED-ON CODE:

6.4 To permit the listing of parts for six models in a single tabulation, a system of used-on codes has been devised. Under this system, a code number has been assigned to each model and appears in the U/O CODE column to indicate that a specific model uses a particular part. When two numbers are separated by a hyphen in the U/O CODE column, it means that the applicable part is used in all models whose codes are between, and inclusive of, the two code numbers. For example, if "1-4" appears in the U/O CODE column, the applicable part is used on the models whose codes are 1 through 4, inclusively. The cross-reference list of codes and models follows:

CODE NO.	QSA Model
1	12-9.3
2	12-13
3	18-6.8
4	18-10.1
5	28-6.0
6	28-8.8

6.5 ORDERING PARTS

6.6 When ordering parts from Sorensen Company, include the Sorensen part number and the unit model number. Address to:

Sorensen Company
Distribution Center
25 Industrial Road
Grenier Industrial Village
Londonderry, N. H. 03063

Table 6-1 Replacement Parts List

REF DES	PART NUMBER	DESCRIPTION	U/O CODE
Capacitors: (uF, Vdc unless noted)			
C1	24-2276-18	250, 10	1-6
C2	24-2409-19	1, 200	1-3, 5, 6
	24-2409-18	0.680, 200	4
C3	24-2544-7	17, 25	1, 2
	24-2460-3	7.3, 40	3
	24-2299-14	13, 50	4
	24-2445-8	5.8, 50	5
	24-2445-9	8.7, 50	6
C4	24-026	0.020, 900Vac	1-6
C5	24-2015-3	0.015, 250	1-6
C6	24-2015-15	0.150, 250	1-6
C7	24-2455-3	3.5, 20	1, 2
	24-2449-3	2.5, 30	3, 4
	24-2453-5	1.8, 40	5, 6
C8	24-2279-10	25, 25	1-6
C9	Not Used		
C10	24-2565	27, 75	1-4
	24-2566	11, 100	5, 6
C11	24-2409-4	0.0033, 200	1-6
C12	24-2409-5	0.0047, 200	1-6
C13	24-2409-6	0.0068, 200	1-6
C14	24-2280-12	50, 50	1-6
C15	24-2275-18	250, 6	2
C16	24-2409-4	0.0033, 200	1-6
Diodes:			
CR1	26-158-1	CER68	1-6
CR2	26-1017	RD5637	1-6
CR3	26-1017	RD5637	1-6
CR4	26-1046-1	MR1120	1, 4
	587382-1	1N1183A	2
	587393-1	1N1200A	3, 5, 6
CR5	26-1046-1	MR1120	1, 4
	587382-1	1N1183A	2
	587393-1	1N1120A	3, 5, 6
CR6	26-1046-1	MR1120	1, 4
	587382-1	1N1183A	2
	587393-1	1N1200A	3, 5, 6
CR7	26-1046-1	MR1120	1, 4
	587382-1	1N1183A	2
	587393-1	1N1200A	3, 5, 6
CR8	Not Used		
CR9	26-158-2	SEN120	1-4
	26-158-3	SEN140	5, 6
CR10	26-264	1N962B	3, 4
	26-263	1N965B	5, 6
CR11	26-158-1	CER68	2
CR12	26-158-1	CER68	2
CR13	26-211	1N750A	1-6
CR14	26-158-1	CER68	1-6
CR15	Not Used		
CR16	Not Used		
CR17	Not Used		
CR18	26-211	1N750A	1-6
Fuse: (250V)			
F1	42-847	4A	1
	42-413	5A	2, 3, 5
	42-415	6A	4, 6
Transistors: (NPN unless noted)			
Q1	18-144	FSC3641	1-6
Q2	18-151	2N3055	5, 6
Q3	18-142	40312	1-6
Q4	18-115	2N697	1, 2
	18-161-4	2N697	3-6
Q5	18-151	2N2055	2, 4, 6
Q6	18-144	FSC3641	1-6
Q7	18-144	FSC3641	1-6
Q8	18-144	FSC3641	1-6
Q9	18-144	FSC3641	1-6
Q10	18-143	PNP	1-6
Q11	18-115	2N697	1-4
	18-161-4	2N697	5, 6
Q12	18-115	2N697	1-4
	18-161-4	2N697	5, 6

Table 6-1 Replacement Parts List (cont'd)

REF DES	PART NUMBER	DESCRIPTION	U/O CODE
Resistors: (ohm, ½W, ±10% unless noted)			
R1	27-1109	390	1-6
R2	27-156	680	1-6
R3	27-152	2.2k	1
	27-133	10k	2, 4
	27-292	3.3k	3, 5
	27-179	15k	6
R4	27-103	1k	2
	27-295	1.5k, 1	4
	28-705	2.7k, 1	6
R5	29-544	5k, 2, ±20%, Pot	1-6
R6	28-117	27.4k, ±1%	1, 2
	28-1307	56.2k, ±1%	3, 4
	28-1323	82k, ±1%	5, 6
R7	27-496-6	0.39, 5, ±5%	1, 2
	27-496-2	0.67, 5, ±5%	5
	28-544	0.5, 5, ±5%	
R8	27-1110	1.2k	1-6
R9	28-1212	182, ±1%	1-6
R10	27-176	1.8k	1-6
R11	27-176	1.8k	1-6
R12	27-160	68	1-6
R13	27-152	2.2k	1-6
R14	27-174	2.7k	1-6
R15	29-486	2k, 4	1-6
R16	Not Used		
R17	28-1213	182, ±1%	3, 4
	28-1214	422, ±1%	5, 6
R18	29-483	400, 4, Pot	1, 2
	29-484	600, 4, Pot	3, 4
	29-485	1k, 4, Pot	5, 6
R19	Not Used		
R20	Not Used		
R21	27-1156	2.7k, 2	1, 2
	27-499-16	4.7k, 5	3, 4
	27-499-14	6.8k, 5	5, 6
R22	190-3908	0.007	1, 2
	190-3909	0.018	5, 6
R23	28-729	1.8k, 1	1, 2
	27-1183	3.9k, 2	3-6
R24	27-1182	270, 2	1
	27-499-13	200, 5	2
	27-466	450, 5	3, 6
	27-457	300, 5	4
	27-458	600, 5	5
R26	29-544	5k, 2, ±20%, Pot	1-6
R27	27-1109	390	1-6
R28	27-133	10k	1-6
R29	Not Used		
R30	Not Used		
R31	Not Used		
R32	Not Used		
R33	Not Used		
R34	Not Used		
R35	Not Used		
R36	27-599-1	75, 10	1, 4
	27-599-3	50, 10	2, 6
	27-599-14	100, 10	3
	27-599-2	150, 10	5
Transformer:			
T1	126-3049		1
	126-3057		2
	126-3050		3
	126-3058		4
	126-3051		5
	126-3059		6

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